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NATIONAL DAM SAFETY PROGRAM. SKY RANCH LAKE DAM (MO 31293), MIS--ETC(U)
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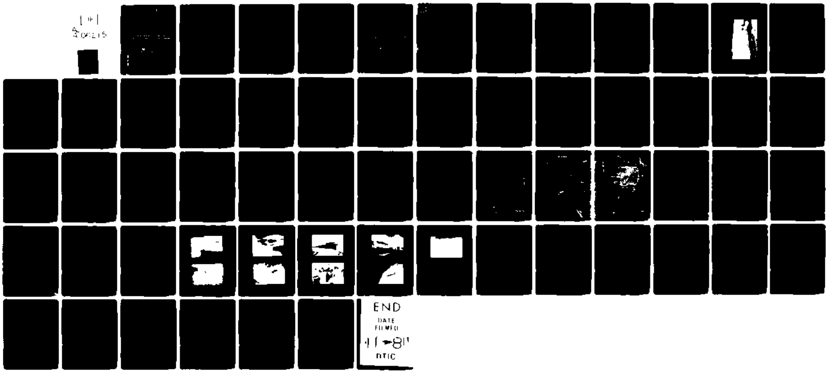

LEVEL II

AD A106215

MISSOURI - KANSAS CITY BASIN

SKY RANCH LAKE DAM

WARREN COUNTY, MISSOURI

MO 31293

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

United States Army
Corps of Engineers
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St. Louis District

PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

SEPTEMBER 1980

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dam Safety, Lake, Dam Inspection, Private Dams

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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MISSOURI - KANSAS CITY BASIN

SKY RANCH LAKE DAM

WARREN COUNTY, MISSOURI

MO 31293

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

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PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

SEPTEMBER 1980

DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 TUCKER BOULEVARD, NORTH
ST. LOUIS, MISSOURI 63101

REPLY TO
ATTENTION OF

LMSED-P

SUBJECT: Sky Ranch Lake Dam, MO 31293, Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Sky Ranch Lake Dam (MO 31293):

It was prepared under the National Program of Inspection of Non-Federal Dams.

This dam has been classified as unsafe, non-emergency by the St. Louis District as a result of the application of the following criteria:

1) Spillway will not pass 50 percent of the Probable Maximum Flood without overtopping the dam.

2) Overtopping of the dam could result in failure of the dam.

3) Dam failure significantly increases the hazard to loss of life downstream.

SUBMITTED BY: SIGNED — 15 OCT 1980
Chief, Engineering Division — Date

APPROVED BY: SIGNED — 15 OCT 1980
Colonel, CE, District Engineer — Date

SKY RANCH LAKE DAM

MISSOURI INVENTORY NO. 31293

WARREN COUNTY, MISSOURI

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

PREPARED BY:

HORNER & SHIFRIN, INC.

5200 OAKLAND AVENUE

ST. LOUIS, MISSOURI 63110

FOR:

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS

CORPS OF ENGINEERS

OCTOBER 1980

HS-8011

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam:	Sky Ranch Lake Dam
State Located:	Missouri
County Located:	Warren
Stream:	Tributary of Lost Creek
Date of Inspection:	9 July 1980

The Sky Ranch Lake Dam was visually inspected by engineering personnel of Horner & Shifrin, Inc., Consulting Engineers, St. Louis, Missouri. The purpose of this inspection was to assess the general condition of the dam with respect to safety and, based upon this inspection and available data, determine if the dam poses a hazard to human life or property.

The following summarizes the findings of the visual inspection and the results of certain hydrologic/hydraulic investigations performed under the direction of the inspection team.[1] Based on the visual inspection and the results of these hydrologic/hydraulic investigations, the present general condition of the dam is considered to be somewhat less than satisfactory. The following deficiencies were noticed during the inspection and are considered to have an adverse effect on the overall safety and future operation of the dam:

1. An eroded section of embankment (up to 6 feet in depth and approximately 8 feet wide and 30 feet long), that appears to be due to spillway releases impinging upon the dam, exists at the junction of the downstream toe of the dam and the spillway outlet channel. Loss of embankment material by erosion can be detrimental to the structural stability of the dam.

2. The upstream face of the dam has only a grass cover to prevent erosion by wave action or fluctuations of the lake surface level. A

grass cover is not considered adequate protection to prevent erosion of the embankment by wave action or fluctuations of the lake surface.

3. Several small trees along with some brushy undergrowth that could conceal animal burrows exists at the waterline along the upstream face of the dam. Tree roots and animal burrows can provide passageways for lake seepage that could develop into a piping condition (progressive internal erosion) and possible failure of the dam.

4. According to survey data obtained during the inspection, the crest elevation of the emergency spillway was found to be approximately 0.1 foot lower than the low area in the top of the dam between stations 1+00 and 1+50. As a result of this suspected settlement, the effectiveness of the emergency spillway is virtually negated.

According to the criteria set forth in the recommended guidelines, the magnitude of the spillway design flood for the Sky Ranch Lake Dam, which is classified as small in size and of high hazard potential, is specified to be a minimum of one-half the Probable Maximum Flood (PMF). Considering the fact that there are but four dwellings, one of which is unoccupied, within the estimated flood damage zone and the fact that the downstream flood plain is fairly broad and that the level of the living quarters of the dwellings within the flood damage zone are at an elevation appreciably above the bank of the downstream channel, it is recommended that the spillway for this dam be designed for one-half the Probable Maximum Flood. The Probable Maximum Flood (PMF) is the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

Results of the hydrologic/hydraulic analysis indicated that the spillways, principal plus emergency, are inadequate to pass lake outflow resulting from a storm of one-half PMF magnitude without overtopping the dam. The spillways are capable, however, of passing lake outflow resulting from the one percent probability (100-year frequency) flood and the outflow corresponding to about

14 percent of the PMF. According to the St. Louis District, Corps of Engineers, the length of the downstream damage zone, should failure of the dam occur, is estimated to be two miles. Within the downstream damage zone are four dwellings, one of which is unoccupied, several farm buildings and State Highway 94.

A review of available data did not disclose that seepage or stability analyses of this dam were performed. This is considered a deficiency and should be rectified.

It is recommended that the Owner take the necessary action within a reasonable time to correct or control the deficiencies and safety defects reported herein. The provision of additional spillway capacity should be pursued on a high priority basis.

Ralph E. Sauthoff

Ralph E. Sauthoff
P. E. Missouri E-19090

Albert B. Becker, Jr.

Albert B. Becker, Jr.
P. E. Missouri E-9168

OVERVIEW SKY RANCH LAKE DAM

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

SKY RANCH LAKE DAM - MO 31293

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PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

SKY RANCH LAKE DAM - MO 31293

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, dated 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of safety inspection of dams throughout the United States. Pursuant to the above, the St. Louis District, Corps of Engineers, directed that a safety inspection of the Sky Ranch Lake Dam be made.

b. Purpose of Inspection. The purpose of this visual inspection was to make an assessment of the general condition of the dam with respect to safety and, based upon available data and this inspection, determine if the dam poses a hazard to human life or property.

c. Evaluation Criteria. This evaluation was performed in accordance with the "Phase I" investigation procedures as prescribed in "Recommended Guidelines for Safety Inspection of Dams", Appendix D to "Report to the Chief of Engineers on the National Program of Inspection of Non-Federal Dams", dated May 1975.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances. The Sky Ranch Lake Dam is an earthfill type embankment rising approximately 34 feet above the natural streambed at the downstream toe of the barrier. The embankment has an upstream slope (above the waterline) of approximately 1v on 1.9h, a crest width of about 14 feet, and a downstream slope on the order of 1v on 3.0h. The length of the dam is approximately 450 feet and the axis of the dam curves moderately away from the lake between abutments. A plan and profile of the dam are shown on Plate 3 and a cross-section of the dam is presented on Plate 4.

The dam has both a principal and an emergency spillway. The principal spillway, a culvert consisting of two 18-inch diameter corrugated metal pipes, is located at the left, or south, end of the dam. A concrete headwall serves to protect the upstream face of the dam at the pipes. The emergency spillway, a shallow V-section with the invert of the crest protected by concrete pavement, is also located at the left end of the dam. The outlet channel for both spillways closely follows the intersection of the embankment and the left abutment joining the original stream channel at a point about 100 feet downstream of the dam centerline. Profiles of the two spillway pipes are shown on Plate 4. The emergency spillway cross-section is shown on Plate 5.

The reservoir has two pipe outlets for lake drawdown. One of the outlets, a 2.5-inch galvanized steel pipe, enters an old cistern located in the downstream side of the dam at a point approximately 140 feet from the right, or north, abutment. A valve located within the cistern serves to control flow in the pipe. According to the Owner, it was intended that the cistern would serve as a storage facility to supply water to the old farm house located just downstream of the cistern. However, the Owner stated that this plan was never implemented and that the old farm house is not used. The second outlet, a 2-inch galvanized steel pipe, is located just to the left of the dam center. A valve located in a small shed near the toe of the dam serves to control flow in the pipe. The outlet pipe for this line, elevated about 3 feet above the ground surface, joins the original stream channel at a point just downstream of the dam. The piping within the shed is protected from freezing by heating tape and lamps as well as insulation attached to the building interior. According to the Owner, the inlet end of the 2-inch diameter pipe projects 8 feet above the bottom of the reservoir at a location just upstream of the base of the dam; the inlet end of the 2.5-inch diameter pipe is near the bottom of the reservoir opposite the cistern, and both pipes have well screen type filters on the inlet ends.

b. Location. The dam is located on an unnamed tributary of Lost Creek, about 1 mile east of the intersection of a private unnamed road and State Highway 94, and approximately 4 miles northwest of the town of Pinkney, Missouri, as shown on the Regional Vicinity Map, Plate 1. The dam is located within U. S. Survey No. 1765, approximately 6,900 feet southeast and 8,700 feet southwest of the northwest corner, within Warren County.

c. Size Classification. The size classification based on the height of the dam and storage capacity, is categorized as small (per Table 1, Recommended Guidelines for Safety Inspection of Dams).

d. Hazard Classification. The Sky Ranch Lake Dam, according to the St. Louis District, Corps of Engineers, has a high hazard potential, meaning that if the dam should fail, there may be loss of life, serious damage to homes, or extensive damage to agricultural, industrial and commercial facilities, important public utilities, main highways, or railroads. The estimated flood damage zone, should failure of the dam occur, as determined by the St. Louis District, extends two miles downstream of the dam. Within the possible flood damage zone are four dwellings, one of which is unoccupied, several farm buildings and State Highway 94. Those features lying within the downstream damage zone reported by the Corps of Engineers, St. Louis District, were verified by the inspection team.

e. Ownership. The lake and dam are owned by Elmer C. Edelmann. Mr. Edelmann's address is Box 211, Rural Route 1, Marthasville, Missouri 63357.

f. Purpose of Dam. The dam impounds water for recreational use.

g. Design and Construction History. According to the Owner, construction of the dam was completed in 1970 and the builder of the dam was Arthur Whaley, an excavator and earth moving contractor, from Jonesburg, Missouri. Efforts to contact Mr. Whaley to ascertain details of the dam design were unsuccessful. Records of the design were unavailable.

h. Normal Operational Procedure. The lake level is unregulated. Lake outflow is governed by the combined capacities of a culvert type spillway, consisting of two 18-inch diameter pipes, and an overflow type emergency spillway.

1.3 PERTINENT DATA

a. Drainage Area. The area tributary to the lake is for the most part in a native state covered with timber. The watershed above the dam amounts to approximately 134 acres. The watershed area is outlined on Plate 2.

b. Discharge at Damsite.

(1) Estimated known maximum flood at dam site ... 11 cfs* (W.S.Elev. 610.5)

(2) Spillway capacity ... 38 cfs.

c. Elevation (Ft. above MSL). The following elevations were determined by survey and are based on topographic data shown on the 1974 Berger, Missouri, Quadrangle Map, 7.5 Minute Series.

(1) Observed pool ... 609.5

(2) Normal pool ... 610.0

(3) Spillway crest

A. Principal ... 610.0

B. Emergency ... 613.8

(4) Maximum experienced pool ... 610.5*

(5) Top of dam ... 613.9 (min.)

(6) Streambed at centerline of dam ... 583± (Est.)

(7) Maximum tailwater ... Unknown

(8) Observed tailwater ... None

d. Reservoir.

(1) Length at normal pool (Elev. 610.0) ... 1,400 ft.

(2) Length at maximum pool (Elev. 613.9) ... 1,500 ft.

e. Storage.

(1) Normal pool ... 51 ac. ft.

(2) Top of dam (incremental) ... 32 ac.ft.

f. Reservoir Surface.

(1) Normal pool ... 8 acres

(2) Top of dam (incremental) ... 1 acre

*Based on an estimate of depth of flow at pipe spillway as observed by the Owner.

g. **Dam.** The height of the dam is defined to be the overall vertical distance from the lowest point of foundation surface at the downstream toe of the barrier, to the top of the dam.

(1) Type ... Earthfill, homogeneous *

(2) Length ... 450 ft.

(3) Height ... 34 ft.

(4) Top width ... 14 ft.

(5) Side slopes

a. Upstream ... 1v on 1.9h (above waterline)

b. Downstream ... 1v on 3.0h

(6) Cutoff ... Core trench*

(7) Slope protection

a. Upstream ... Grass

b. Downstream ... Grass

h. Principal Spillway.

(1) Type ... Uncontrolled, two 18-inch diameter corrugated metal pipes (culvert)

(2) Location ... Left abutment

(3) Crest ... Elevation 610.0 & 610.4

(4) Outlet channel ... Excavated earth, irregular trapezoidal section

i. Emergency Spillway.

(1) Type ... Uncontrolled, V-section, paved concrete invert at crest

(2) Location ... Left abutment

(3) Crest ... Elevation 613.8

(4) Outlet channel ... Common with principal spillway outlet channel

*Per Owner

j. Lake Drawdown Facility.

(1) Pipe, 2.5-inch diameter with control valve and outlet in old cistern located in downstream face of dam at station 2+50±.

(2) Pipe, 2.0-inch diameter with control valve in shed located near downstream toe of dam at station 1+10±.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

Data relative to the design of the dam were unavailable.

2.2 CONSTRUCTION

As previously stated, the dam was constructed in 1970 by Arthur Whaley, a local earth excavating contractor. According to the Owner, a core trench for seepage cutoff was excavated along the axis of the dam. The Owner reported that the material used to backfill the trench and construct the dam was clay that was obtained from the hillside just north of the lake. The Owner also recalled that the embankment material was compacted using a sheepsfoot roller. Records of the construction of the dam were unavailable.

2.3 OPERATION

The lake level is uncontrolled and governed by the elevation of the crest of the southern most of two 18-inch diameter pipes. No indication was found that the dam has been overtopped. The Owner reported that the dam has never been overtopped and that to his knowledge, the highest lake level experienced to date produced a depth of flow at the pipe spillway estimated to be about 6 inches above the invert of the south pipe.

2.4 EVALUATION

a. Availability. Engineering data for assessing the design of the dam and spillways were unavailable.

b. Adequacy. No data available. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. A visual inspection of the Sky Ranch Lake Dam was made by Horner & Shifrin engineering personnel, R. E. Sauthoff, Civil Engineer, and A. B. Becker, Jr., Civil and Soils Engineer, on 9 July 1980. An examination of the dam area was also made by an engineering geologist, Jerry D. Higgins, Ph.D., a consultant retained by Horner & Shifrin for the purpose of assessing the site geology. Also examined at the time of the inspection were the areas and features below the dam within the potential flood damage zone. Photographs of the dam taken at the time of the inspection are included on pages A-1 through A-5 of Appendix A. The locations of the photographs taken during the inspection are indicated on Plate 3.

b. Site Geology. The lake and dam are located within the Ozark Plateaus Physiographic Province near the border with the Dissected Till Plains Section of the Central Lowlands Province. The topography is moderately rugged, and there is up to approximately 280 feet of relief between the reservoir and the surrounding drainage divides. In the general area, the bedrock formations consist of gently northward-dipping Ordovician-age dolomites of the Jefferson City-Cotter formation and sandstones of the St. Peter formation. The dam and reservoir are situated on Jefferson City-Cotter dolomite with the St. Peter sandstone exposed well above the reservoir level. No faulting was observed or has been reported in the vicinity of the site.

The Jefferson City-Cotter dolomite is a light brown, medium to finely crystalline dolomite or argillaceous dolomite. It is thin- to medium-bedded, often argillaceous, and cherty. Solution enlargement of joints and bedding planes frequently occurs in the dolomite, and the contact between bedrock and the overlying surficial materials is usually an irregular surface. Jefferson City-Cotter dolomites outcrop in the spillway channel. The St. Peter sandstone is a white, fine- to medium-grained, pure quartz sandstone. It generally is massively bedded and although loosely cemented, exposed rock surfaces usually are case hardened by weathering processes.

The unconsolidated surficial materials are composed principally of soils of the Winfield series overlying residual clays. This series consists of deep, well-drained soils derived from the wind-deposited silts on the uplands adjacent to the Missouri River Valley. The soils consist of light brown silts in the upper layers, becoming darker and more clayey with depth. According to the Unified Soil Classification System, they are classified as CL or CL-ML materials, are moderately permeable and susceptible to erosion, but are generally suited for embankments and water impoundments. The bottom of the valley beneath the reservoir is covered by alluvial soils of the Cedargap and Nodaway series. The Cedargap series consists of a dark, grayish-brown silt grading with depth to a very cherty clay. The soils are classified as ML to GC material, are permeable, and may be subject to piping. The Nodaway series consists of a dark brown silt. The soils are classified as CL or CL-ML materials and are moderately permeable. Seepage may be common in both alluvial soils. Residual cherty clays are exposed in the dam abutments. These soils typically are somewhat permeable and often cause some seepage from reservoirs.

No geologic condition was noted that would be considered to severely affect the stability or performance of the dam or reservoir.

c. Dam. The visible portions of the upstream and downstream faces of the dam (see Photos 1, 2 and 7) as well as the dam crest were inspected and, except as noted herein, found to be in sound condition. No surface cracks or sloughing of the embankment slopes were noted. A section of embankment, approximately 30 feet long and 8 feet wide, was eroded to a depth of about 6 feet at a location adjacent to the lower end of the spillway outlet channel. No other significant erosion of the dam was noticed. No seepage was observed at the dam or in the area adjacent to the downstream toe of the dam. Except for the dam crest, which had a combination of turf that had been recently mowed, and crushed stone surfacing, the grass on the dam was about 3 feet high at the time of the inspection. Several small willow trees on the order of 1 inch in diameter along with some brushy undergrowth were found along the unprotected (no riprap) upstream face of the dam near the normal waterline. Examination of a soil sample obtained from the downstream face of the dam indicated the surficial material of the embankment to be a brown, silty lean clay (CL) of low-to-medium plasticity.

The visible portions of the two 18-inch diameter corrugated metal spillway pipes (see Photos 3 and 4) including the pole structure at the upstream end of the pipes were examined and found to be in satisfactory condition. According to the Owner, the poles are intended to support a dock that is planned to be constructed at some future time. The concrete headwall that serves to protect the upstream face of the dam at the pipes was also inspected and found to be in good condition without cracks or deterioration due to weathering. Some minor erosion of the embankment at the downstream ends of the pipes was evident; however, it did not appear to be significant. Inspection of the concrete slab (see Photo 5) that serves to protect the top of the dam at the emergency spillway indicated the pavement to be in satisfactory condition without cracks or spalls. Some minor erosion of the spillway outlet channel invert was noticed; however, it appeared that most of the channel bottom between the spillway pipes and the downstream channel was protected by bedrock outcrops. As previously stated, erosion that appeared to be due to spillway releases, has damaged a section of the embankment adjacent to the spillway outlet channel.

According to survey data obtained during the inspection, the crest elevation of the emergency spillway was found to be approximately 0.1 foot lower than the low area in the top of the dam between stations 1+00 and 1+50. It appears likely that the dam has settled to some extent in the vicinity of stations 1+00 to 1+50; however, the extent of the possible settlement in this area could not be determined.

The visible portions of the two lake drawdown pipes and appurtenances were examined and both features appeared to be in satisfactory condition. The 2-inch diameter pipe system within the shed (see Photo 6) was protected from freezing by heating tape and lamps as well as by insulation secured to the interior of the structure. The 2.5-inch diameter pipe outlet within the cistern (see Photo 8) was exposed to the weather at the time of the inspection.

The cistern, a concrete block structure parged with mortar and about 6.5 feet in diameter, was inspected and no serious defects were noted. The bottom of the cistern was sounded and found to about 19.5 feet below the top of the structure which was approximately 5 feet below the top of the dam. The water

level within the cistern was approximately 8.5 feet below the top at the time of the inspection. The incoming lake drawdown pipe was located about 3.5 feet below the top and the outlet pipe was approximately 7.5 feet below the cistern top. The upper 8 feet of the structure appeared to be newer than the lower portion and was probably added when the dam was built.

d. Appurtenant Structures. Except for the lake drawdown pipes, there are no appurtenant structures at this dam.

e. Downstream Channel. Except as noted herein, the downstream channel is unimproved. A culvert type structure allows State Highway 94 to cross the stream at a point about 1 mile downstream of the dam. A bridge conveys a railroad over the stream at a point almost 2 miles downstream of the dam just upstream of its juncture with the Missouri River. Between the dam and Highway 94 two low-water type crossings allow the road that accesses the Owner's property to cross the tributary. The tributary joins Lost Creek at a point about 1.5 miles downstream of the dam.

f. Reservoir. At the time of the inspection, the reservoir was approximately 0.5 feet below normal level and clear. No erosion of the lake banks was evident. Except for a section near the north end of the dam, the area about the lake was tree covered. The amount of sediment within the lake could not be determined during the inspection; however, due to the vegetation covering the surrounding area, it is not expected to be significant.

3.2 EVALUATION

The deficiencies observed during the inspection and noted herein, are not considered of significant importance to warrant immediate remedial action.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

The spillways are uncontrolled. The lake surface level is governed by precipitation runoff, evaporation, seepage, and the combined capacities of the uncontrolled spillways.

4.2 MAINTENANCE OF DAM

According to the Owner, in 1979, a concrete diaphragm (wall) approximately 18 inches wide, 12 feet deep and 20 feet long, was installed in the dam at the location of the two culvert type spillway pipes. The Owner reported that muskrats had tunneled into the embankment adjacent to the pipes and that the purpose of the wall was to prevent erosion by piping of the dam at the spillway location. Since installation of the wall, the Owner indicated that there have been no problems with muskrats or erosion at the spillway location. The Owner also reported that muskrats are removed from the dam area by trapping.

4.3 MAINTENANCE OF OUTLET OPERATING FACILITIES

With the exception of the valves on the two lake drawdown pipes, no outlet facilities requiring operation exist at this dam. The valves on both lake drawdown pipes appeared to be in good condition, although neither valve was operated to check performance. As previously stated, the valve located in the shed at the base of the dam is protected from freezing by heat tape and lamps, whereas the valve located in the old cistern is exposed to the weather. There is no reservoir regulation plan.

4.4 DESCRIPTION OF ANY WARNING SYSTEMS IN EFFECT

The inspection did not reveal the existence of a dam failure warning system.

4.5 EVALUATION

It is recommended that maintenance of the dam also include periodic cutting of grass on the slopes and the removal of the small trees along the upstream face of the dam. Provisions should also be taken to prevent further erosion of the embankment at the left side of the dam adjacent to the spillway outlet channel. It is also recommended that a detailed inspection of the dam be instituted on a regular basis by an engineer experienced in the design and construction of dams and that records be kept of all inspections made and remedial measures taken.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. Design data were not available.

b. Experience Data. The drainage area and lake surface area were developed from the 1974 USGS Berger, Missouri, Quadrangle Map. The proportions and dimensions of the spillways and dam were developed from surveys made during the inspection. Records of rainfall, streamflow, or flood data for the watershed were not available.

Due to the fact that the watershed for this reservoir is small, the lake level was assumed to be at normal pool as a result of antecedent storms prior to occurrence of the PMF and the probabilistic storm.

According to the St. Louis District, Corps of Engineers, the estimated flood damage zone, should failure of the dam occur, extends two miles downstream of the dam. The embankment for State Highway 94, which crosses the stream at a point about one mile downstream of the dam, is expected to act as a barrier in the event of dam failure.

c. Visual Observations.

(1) The dam has both a principal and an emergency spillway. The principal spillway, a culvert type installation consisting of two 18-inch diameter corrugated metal pipes, is located near the left abutment of the dam. The emergency spillway, a V-section with the crest protected by a concrete slab, is also located at the left abutment.

(2) A single outlet channel serves both spillways. The channel follows closely the junction of the dam and the abutment joining the original stream on which the dam is constructed just downstream of the dam.

(3) Spillway releases have caused damage by erosion to an area of the embankment adjacent to the outlet channel.

(4) The reservoir has two outlets for lake drawdown. One outlet consists of a 2.5-inch diameter pipe that has its control valve within a cistern located in the downstream face of the dam. A 2.5-inch diameter pipe extends from the cistern at a lower elevation than the control valve, but presently is capped near the cistern. The second outlet consists of a 2-inch diameter pipe that has its control valve within a shed located at the downstream toe of the dam. A 2-inch diameter discharge line conducts flow to the downstream channel at a point just downstream of the dam.

d. Overtopping Potential. The spillways are inadequate to pass the probable maximum flood, or 1/2 the probable maximum flood, without overtopping the dam. The results of the dam overtopping analyses are as follows:

(Note: The data appearing in the following table has been extracted from the computer output data appearing in Appendix B. Decimal values have been rounded to the nearest one-tenth in order to prevent assumption of unwarranted accuracy.)

Ratio of PMF	Q-Peak Outflow (cfs)	Max. Lake W.S. Elev.	Max. Depth (Ft.) of Flow over Dam (Elev. 613.9)	Duration of Overtopping of Dam (Hours)
0.50	1,435	615.4	1.5	7.4
1.00	2,998	616.2	2.2	11.7

Elevation 613.9 was found to be the lowest point in the dam crest. The flow safely passing the spillway, just prior to overtopping amounts to approximately 38 cfs, which is the routed outflow corresponding to about 14 percent of the probable maximum flood inflow. During peak flow of the probable maximum flood, the greatest depth of flow over the dam is projected to be 2.2 feet and overtopping will extend across the entire length of the dam.

e. Evaluation. Examination of the surficial material of the dam indicated it to be a brown, silty lean clay of low-to-medium plasticity. Experience indicates that this type of material, under certain conditions,

such as high velocity flow, can be very erodible. An example of such erosion exists along the downstream toe of the embankment adjacent to the spillway outlet channel. Such a condition exists during the PMF when large lake outflow, accompanied by high flow velocities, occurs. For the PMF condition where the depth of flow over the dam crest, a maximum of 2.2 feet, and the duration of flow over the dam, 11.7 hours, are appreciable, damage by erosion to the crest and downstream face of the dam is expected. The extent of these damages is not predictable within the scope of these investigations; however, there is a possibility that they could result in failure by erosion of the dam. A similar condition, although not quite as severe, also exists during the 1/2 PMF event.

f. References. Procedures and data for determining the probable maximum flood, the 1 percent probability flood, and the discharge rating curve for flow passing the spillways are presented on pages B-1 thru B-3 of the Appendix. Listings of the HEC-1 (Dam Safety Version) input data for both the probable maximum flood and the 1 percent probability flood are shown on pages B-4 through B-6. Computer output data, including unit hydrograph ordinates, tabulation of PMF rainfall, loss and inflow data are shown on pages B-7 through B-10; tabulation of lake surface area, elevation and storage volume is shown on page B-11; and tabulations titled "Summary of Dam Safety Analysis" for the PMF and 1 percent probability (100-year frequency) flood are also shown on page B-11.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations. Visual observations of conditions which adversely affect the structural stability of the dam are discussed in Section 3, paragraph 3.1c.

b. Design and Construction Data. No design or construction data relating to the structural stability of the dam are known to exist. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

c. Operating Records. With the exception of the valves on the two lake drawdown pipes, no appurtenant structures or facilities requiring operation exist at this dam. According to the Owner, no records are kept of the lake level, spillway discharge, dam settlement, or seepage.

d. Post Construction Changes. As discussed in Section 4, paragraph 4.2, in 1979 a concrete diaphragm (wall) was installed in the dam at the location of the spillway pipes in order to prevent erosion of the embankment. According to the Owner, no other post construction changes have been made or have occurred which would affect the structural stability of the dam.

e. Seismic Stability. The dam is located in an area close to the boundary separating the Zone I and Zone II seismic probability areas. An earthquake of the magnitude that might occur in this area would not be expected to cause structural damage to a well-constructed earth dam of this size provided that static stability conditions are satisfactory and conventional safety margins exist. However, it is recommended that the prescribed seismic loading be applied in any stability analyses performed for this dam.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. A hydraulic analysis indicated that the spillway is capable of passing lake outflow of about 38 cfs without the level of the lake exceeding the low point in the top of the dam. A hydrologic analysis of the lake watershed area, as discussed in Section 5, paragraph 5.1d, indicates that for storm runoff of one-half probable maximum flood magnitude, the recommended spillway design flood for this dam, the lake outflow would be about 1,435 cfs, and that for the 1 percent probability (100-year frequency) flood, the lake outflow would be about 35 cfs.

Seepage and stability analyses of the dam were not available for review, and therefore, no judgment could be made with respect to the structural stability of the dam.

Significant items noticed during the inspection that could adversely affect the safety of the dam were the embankment erosion adjacent to the spillway outlet channel, the lack of adequate slope protection to prevent erosion of the upstream face of the dam, the small trees and undergrowth along the upstream face of the dam, and possible settlement of the dam crest.

b. Adequacy of Information. Due to lack of design and construction data, the assessments reported herein were based on external conditions as determined during the visual inspection. The assessments of the hydrology of the watershed and capacities of the spillways were based on a hydrologic/ hydraulic study as indicated in Section 5. Seepage and stability analyses comparable to the requirements of "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

c. Urgency. The remedial measures recommended in paragraph 7.2 for the items concerning the safety of the dam noted in paragraph 7.1a should be accomplished within a reasonable time. The item recommended in paragraph 7.2a concerning the provision of additional spillway capacity should be pursued on a high priority basis.

d. <u>Necessity for Phase II</u>. Based on the results of the Phase I inspection, Phase II investigation is not recommended.

e. <u>Seismic Stability</u>. The dam is located in an area close to the boundary separating the Zone I and Zone II seismic probability areas. An earthquake of the magnitude that might occur in this area would not be expected to cause structural damage to a well constructed earth dam of this size provided that static stability conditions are satisfactory and conventional safety margins exist. However, it is recommended that the prescribed seismic loading be applied in any stability analyses performed for this dam.

7.2 REMEDIAL MEASURES

a. <u>Recommendations</u>. The following actions are recommended.

(1) Based upon criteria set forth in the recommended guidelines, spillway size and/or height of dam should be increased in order to pass lake outflow resulting from a storm of one-half the probable maximum flood magnitude, which is the recommended spillway design flood for this dam. In any event, the Owner should address the relationship of the crest elevation of the emergency spillway and the low area of the top of the dam between stations 1+00 and 1+50; since the effectiveness of the emergency spillway is virtually negated under the existing condition.

(2) Obtain the necessary soil data and perform dam seepage and stability analyses in order to determine the structural stability of the dam for all operational conditions. Seepage and stability analyses should be performed by a qualified professional engineer experienced in the design and construction of earthen dams.

b. <u>Operations and Maintenance (O & M) Procedures</u>. The following O & M Procedures are recommended:

(1) Restore the embankment at the eroded area adjacent to the spillway outlet channel and provide some form of protection in order to

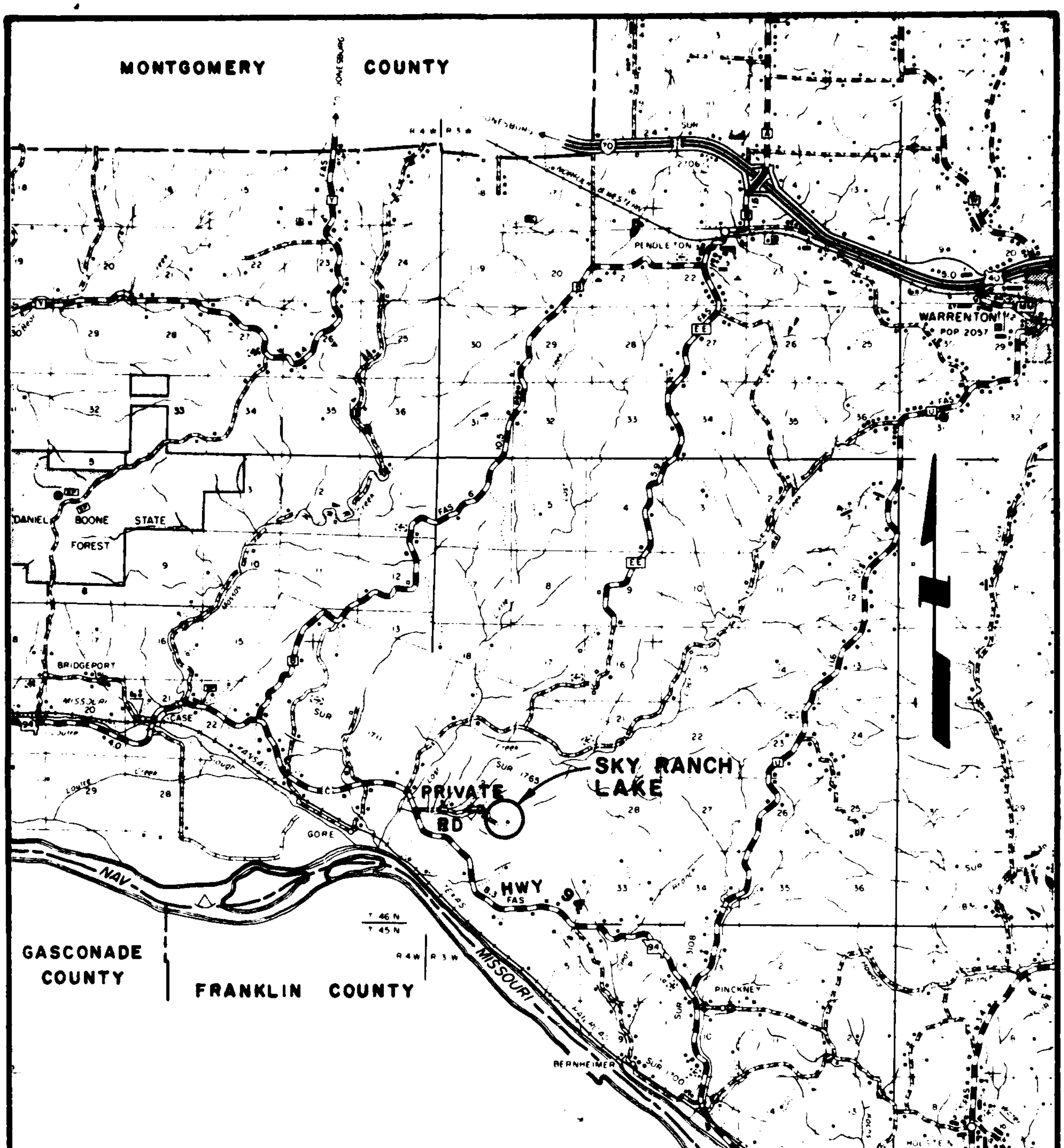
prevent erosion by spillway releases. Loss of embankment material by erosion can impair the structural stability of the dam.

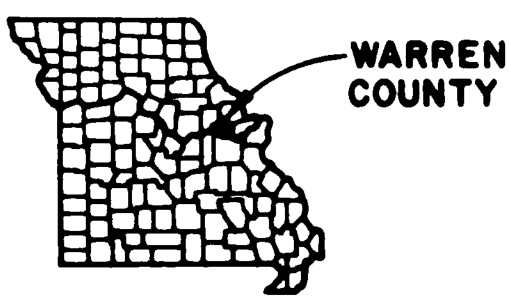
(2) Provide some form of protection other than grass along the upstream face of the dam at and above the normal waterline in order to prevent erosion. A grass covered slope is not considered adequate protection to prevent erosion of the embankment by wave action or by a fluctuating lake level.

(3) Remove the trees and brushy type undergrowth that may conceal animal burrows from the upstream face of the dam. Tree roots and animal burrows can provide passageways for lake seepage that could lead to a piping condition and failure of the dam.

(4) Provide maintenance of all areas of the dam including periodic cutting of the grass on the slopes, on a regularly scheduled basis in order to insure features of being in satisfactory operational condition.

(5) A detailed inspection of the dam should be instituted on a regular basis by an engineer experienced in the design and construction of dams. It is also recommended, for future reference, that records be kept of all inspections made and remedial measures taken.



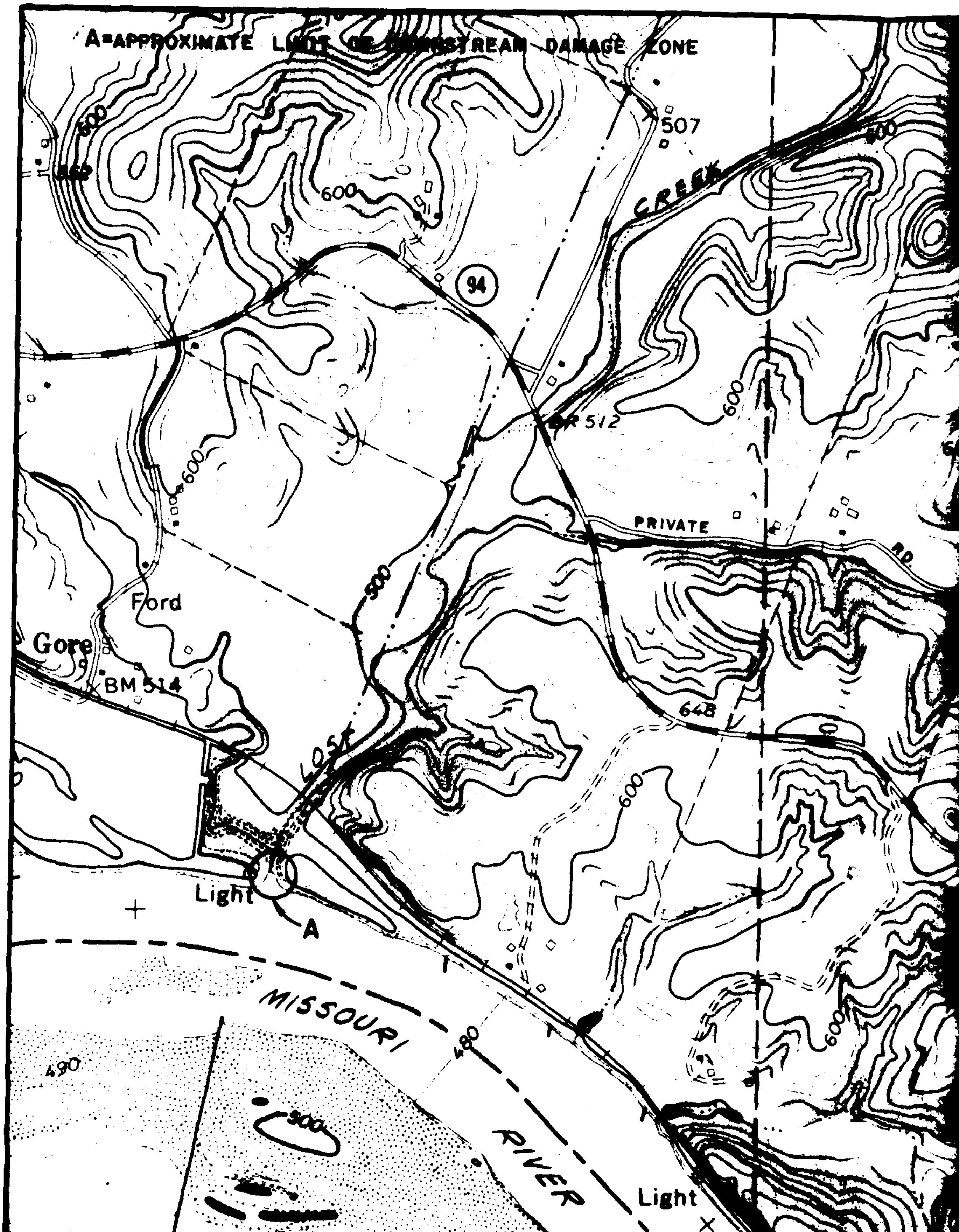


LOCATION MAP

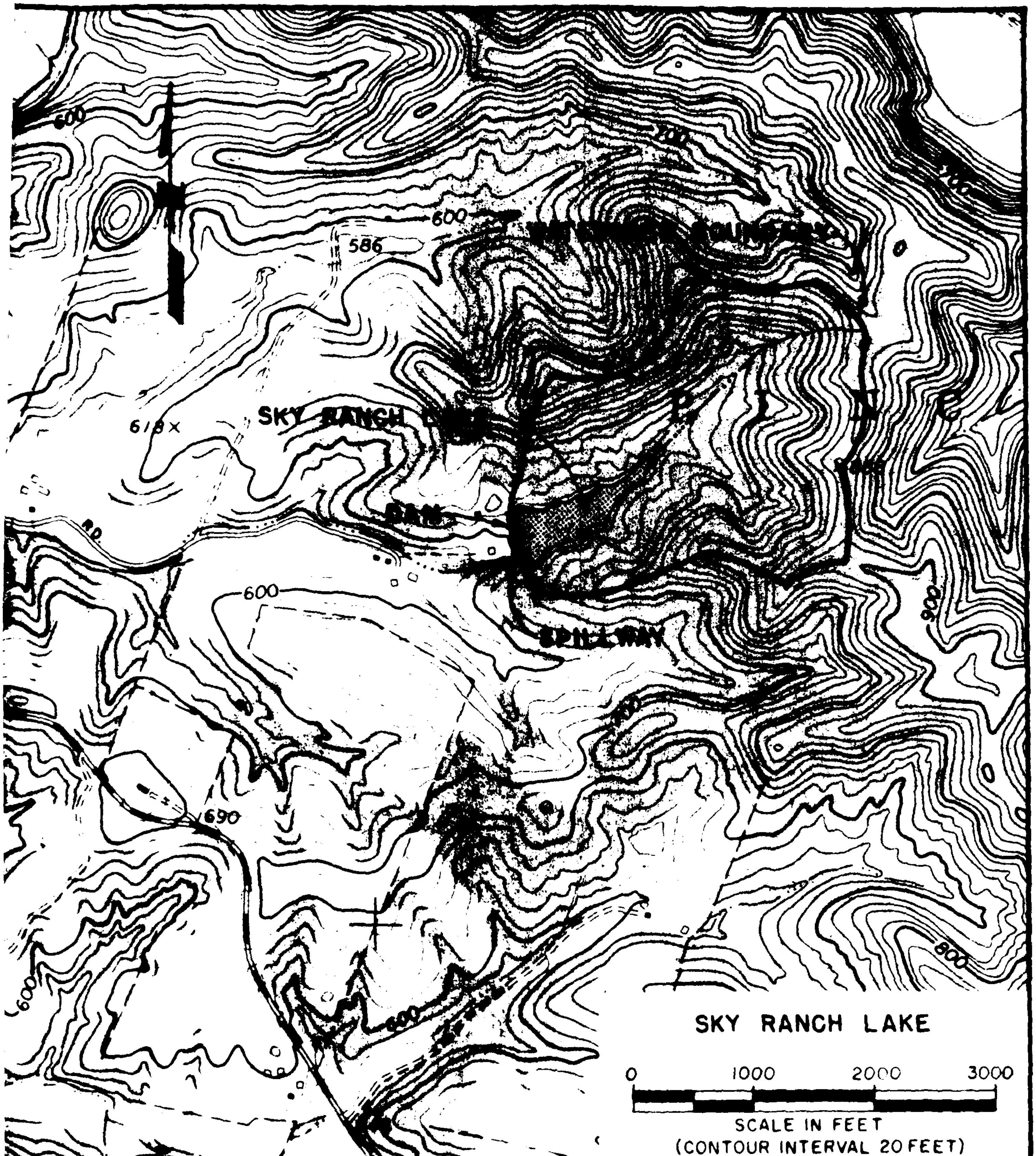
SKY RANCH LAKE

REGIONAL VICINITY MAP

PLATE I



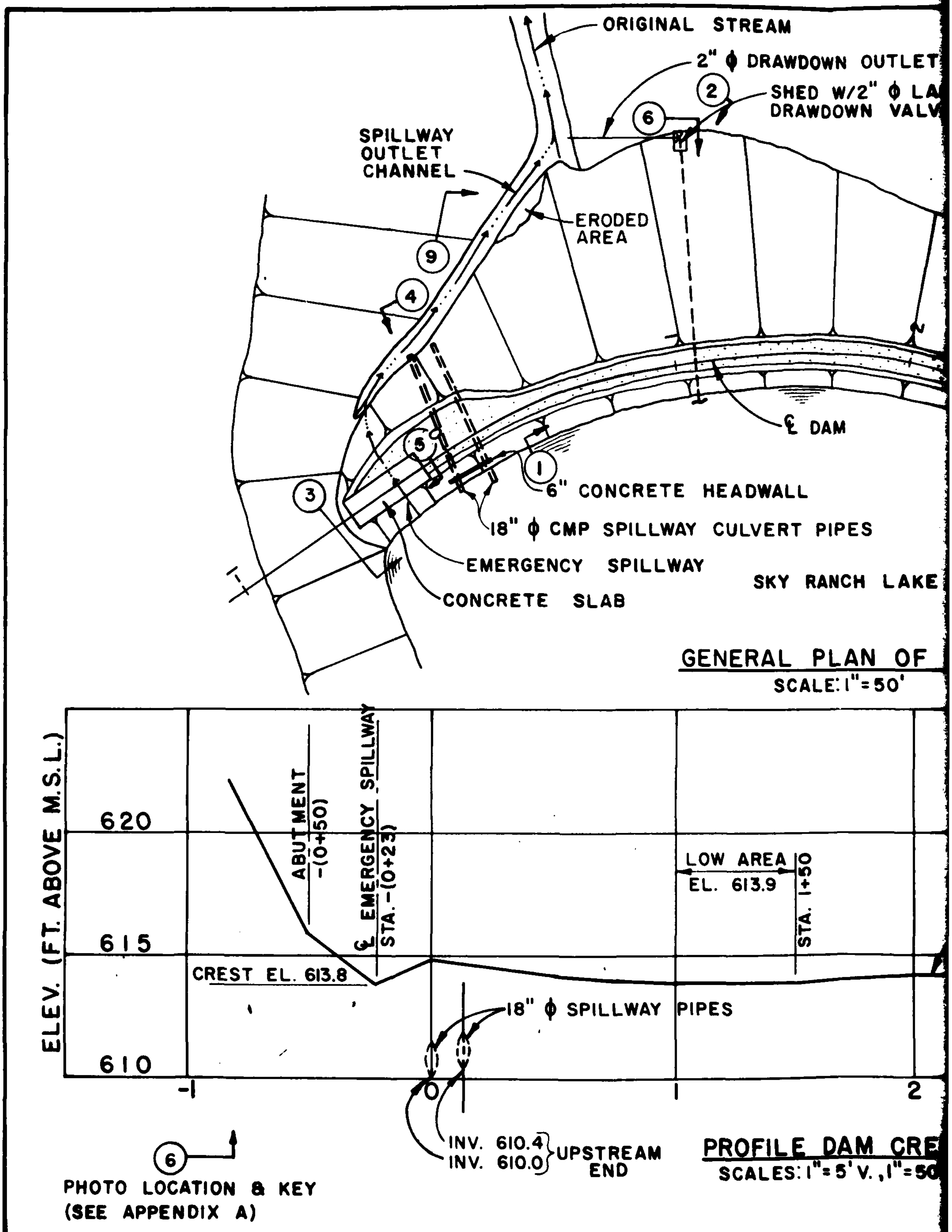
A=APPROXIMATE LIMIT OF DOWNSTREAM DAMAGE ZONE
507
600
CREEK
94
BM 512
PRIVATE
RD.
Ford
Gore
BM 514
648
LOST
Light
A
MISSOURI
RIVER
480
490
500
Light
Mile



SKY RANCH LAKE

LAKE WATERSHED MAP

PLATE 2

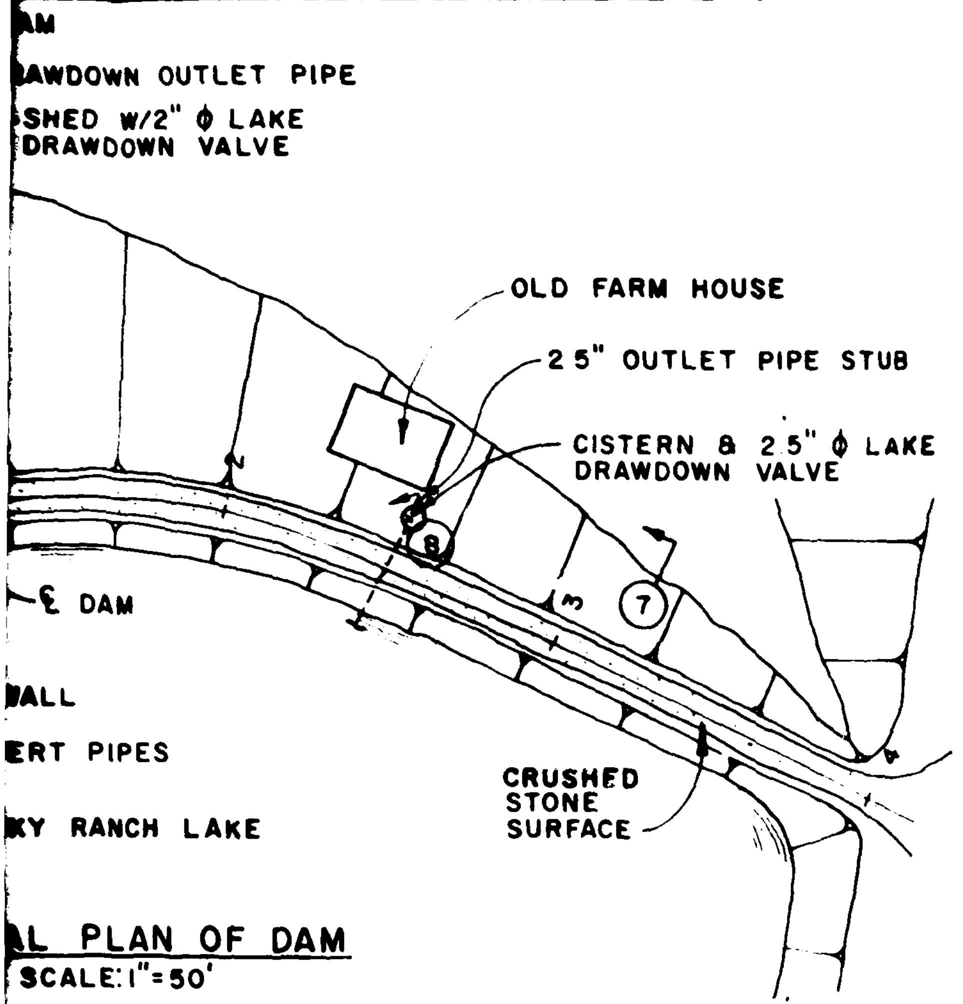


GENERAL PLAN OF

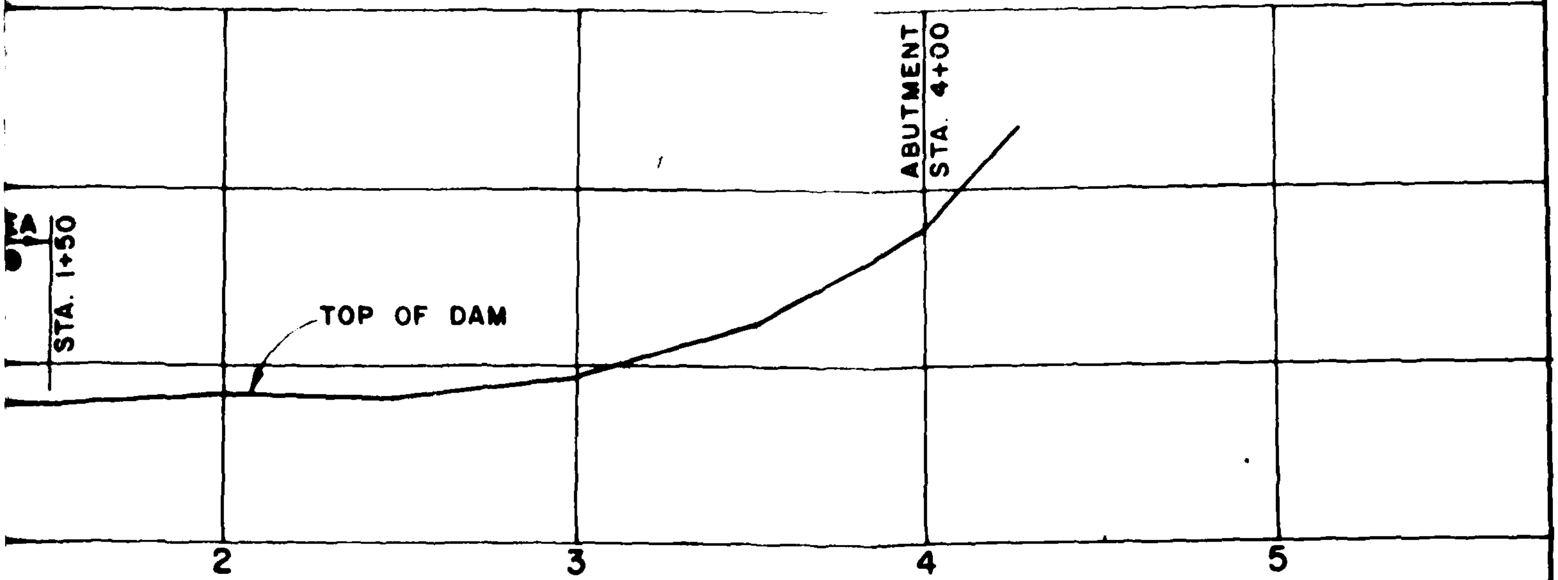
SCALE: 1" = 50'

PROFILE DAM CRE

SCALES: 1" = 5' V., 1" = 50



AL PLAN OF DAM
SCALE: 1"=50'

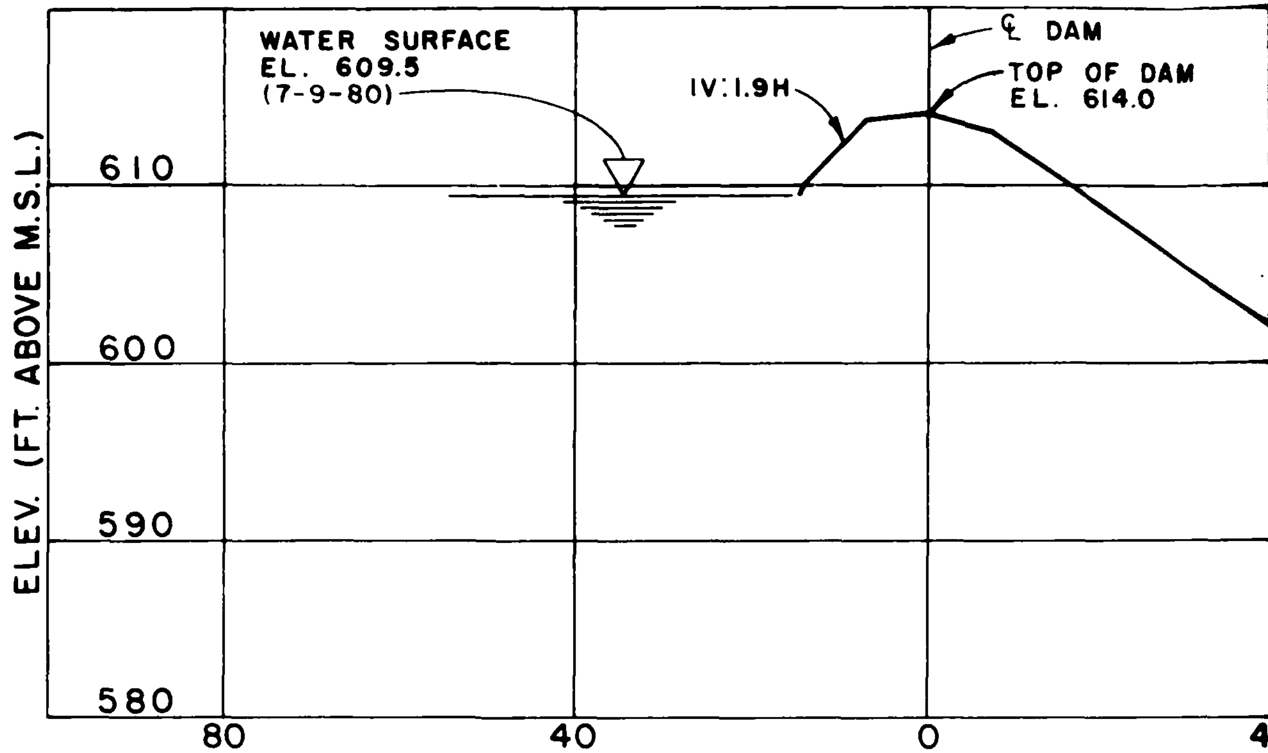


LE DAM CREST
ES: 1"=5' V., 1"=50' H.

SKY RANCH LAKE
DAM PLAN & PROFILE

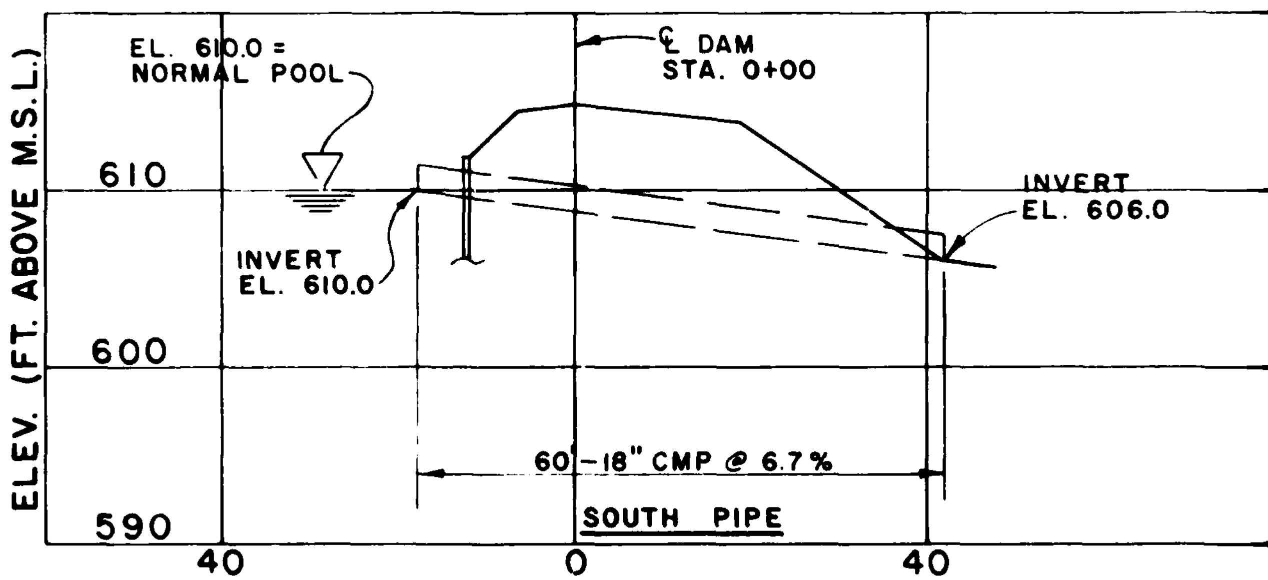
Horner & Shifrin, Inc. August 1980

PLATE 3



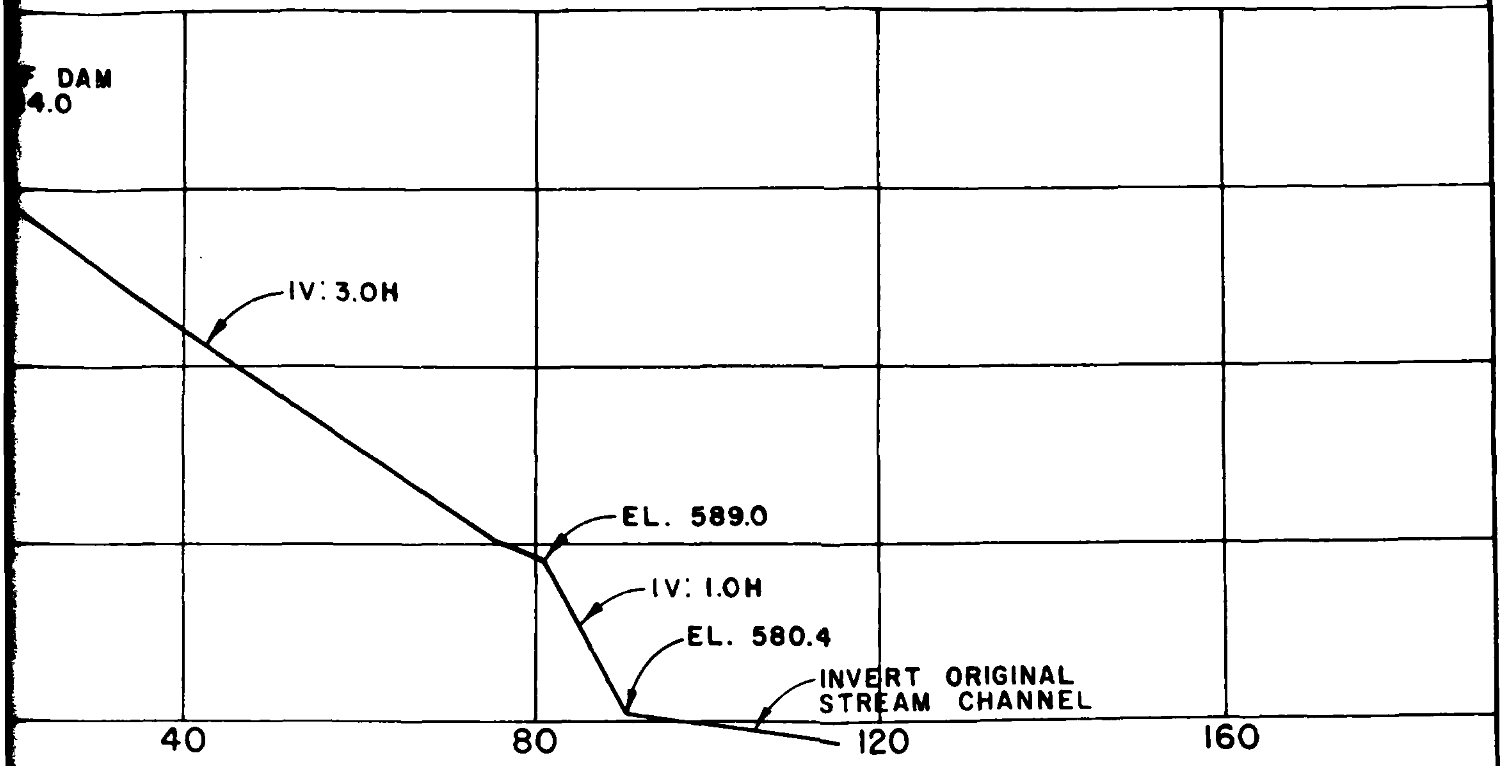
DAM CROSS-SEC

SCALES: 1"



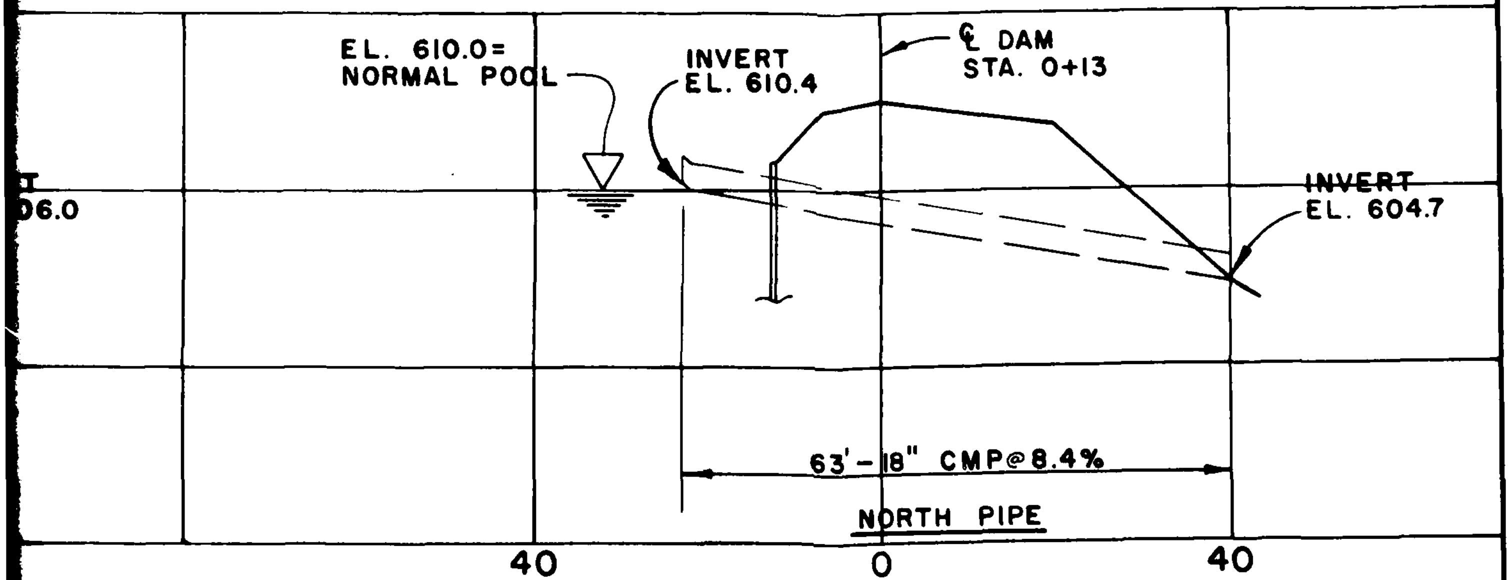
SPILLWAY P

SCALES: 1"



ROSS-SECTION STA. 0+75

SCALES: 1"=10'V., 1"=20'H.



LWAY PIPE PROFILES

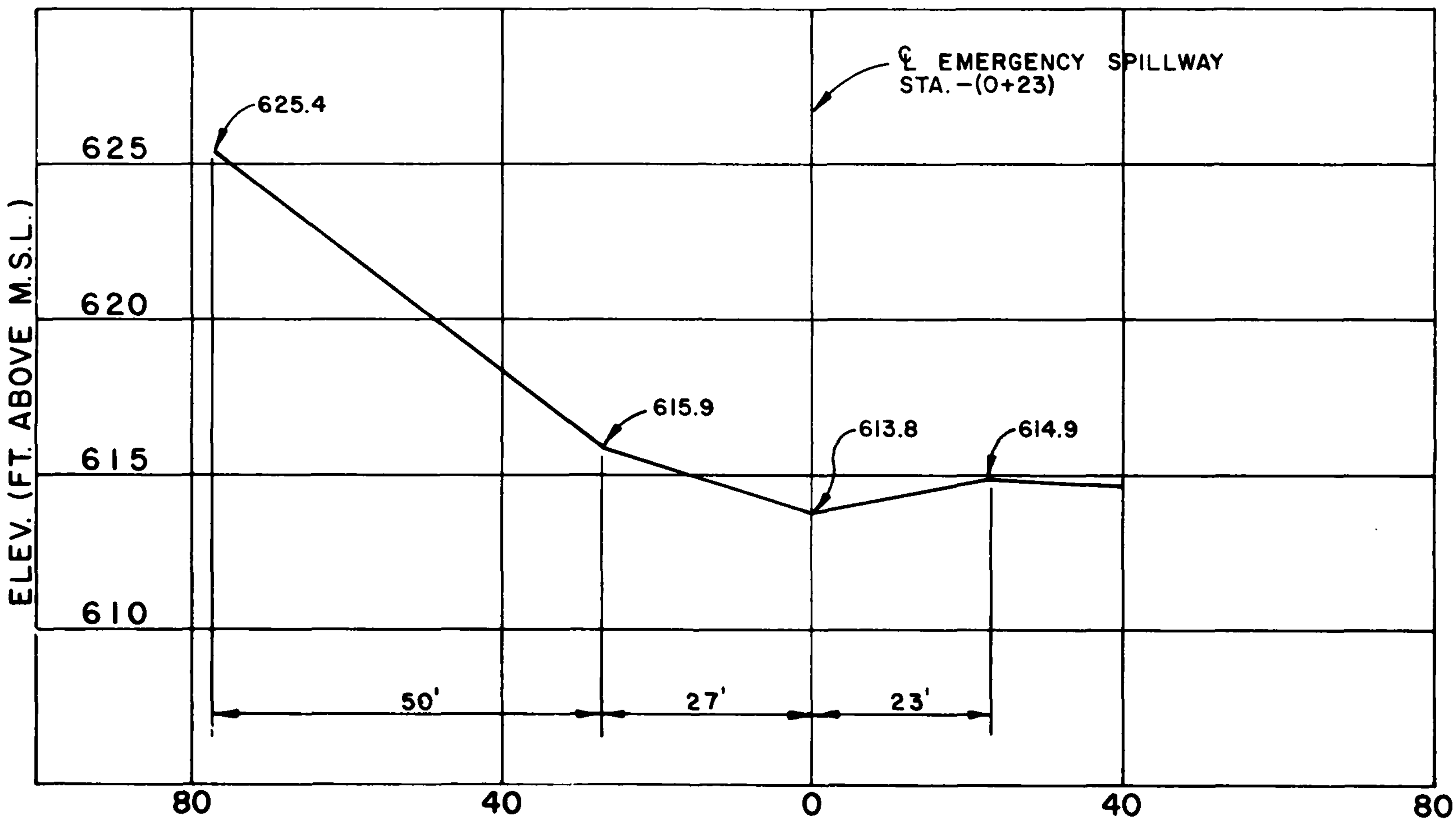
ALES: 1"=10'V., 1"=20'H.

SKY RANCH LAKE
DAM CROSS-SECTION &
SPILLWAY PROFILES

Horner & Shifrin, Inc. August 1980

1 2

PLATE 4



EMERGENCY SPILLWAY CROSS-SECTION — ℄ DAM

SCALES: 1" = 5'V., 1" = 20'H.

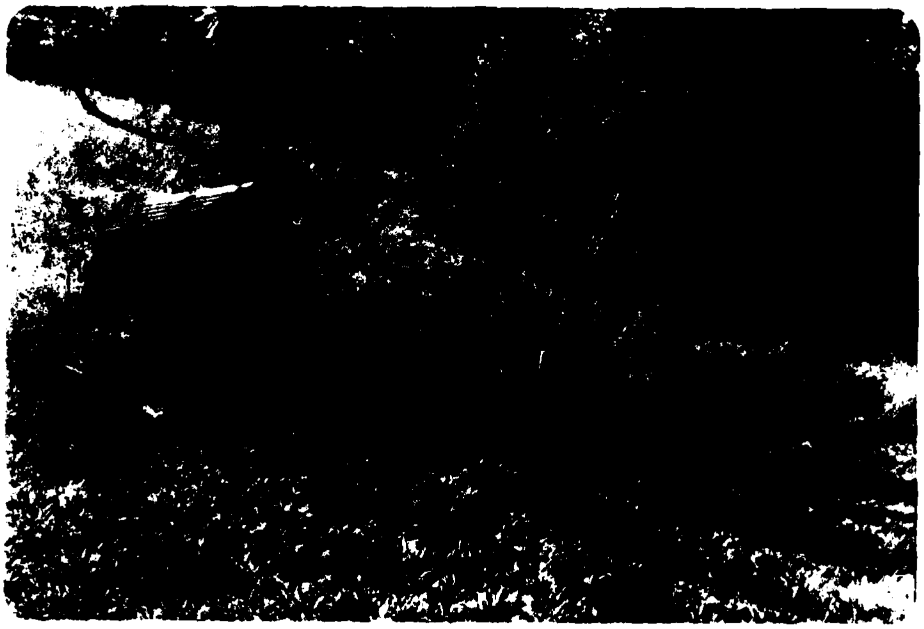
SKY RANCH LAKE
EMERGENCY SPILLWAY
CROSS-SECTION

Horner & Shifrin, Inc. Sept. 1980

APPENDIX A

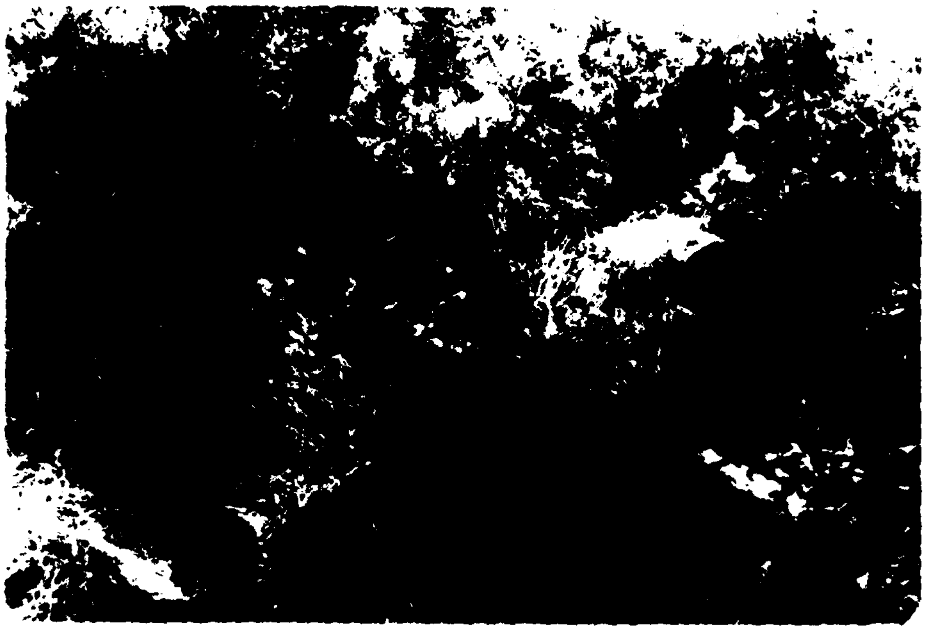
INSPECTION PHOTOGRAPHS

NO. 1: UPSTREAM FACE OF DAM



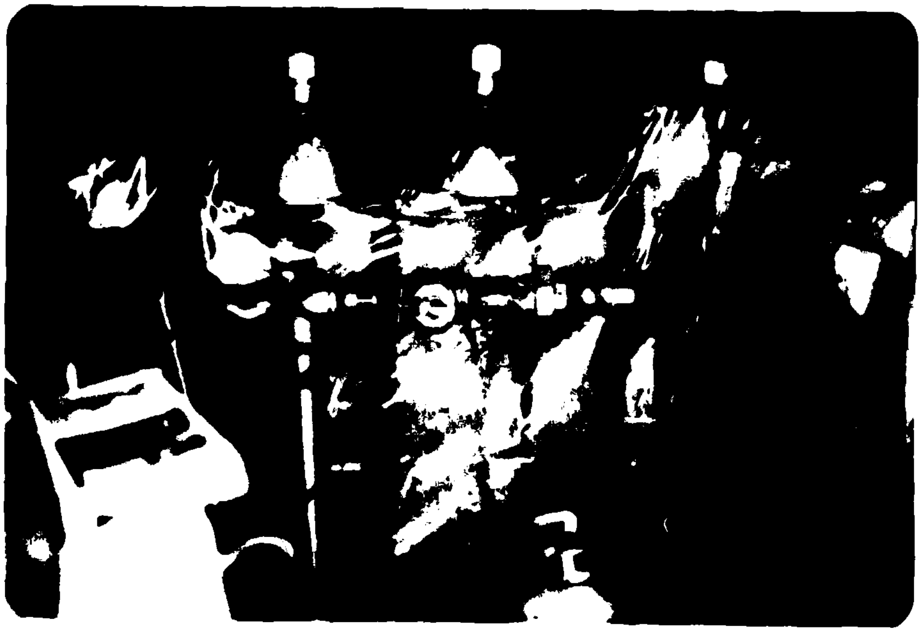
NO. 2: VALVE SHED AT DOWNSTREAM TOE OF DAM

NO. 3: UPSTREAM END OF SPILLWAY PIPES



NO. 4: DOWNSTREAM END OF SPILLWAY PIPES

NO. 5: CONCRETE SLAB AT CREST
OF EMERGENCY SPILLWAY



NO. 6: 2" LAKE DRAWDOWN PIPING WITHIN SHED

NO. 7: CISTERN AND OLD HOUSE IN DOWNSTREAM FACE OF DAM

NO. 8: 2½" LAKE DRAWDOWN PIPING IN CISTERN

NO. 9: EMBANKMENT EROSION ADJACENT TO SPILLWAY OUTLET CHANNEL

APPENDIX B

HYDROLOGIC AND HYDRAULIC ANALYSES

HYDROLOGIC AND HYDRAULIC COMPUTATIONS

1. The HEC-1 Dam Safety Version (July 1978, Modified 26 February 1979) program was used to develop inflow and outflow hydrographs and dam overtopping analyses, with hydrologic inputs as follows:

   a. Probable maximum precipitation (200 sq. mile, 24-hour value equals 25.1 inches) from Hydrometeorological Report No. 33. The precipitation data used in the analysis of the 1 percent probability flood was provided by the St. Louis District, Corps of Engineers.

   b. Drainage area = 0.209 square miles = 134 acres.

   c. SCS parameters:

   Time of Concentration (T_c) = $\left(\frac{11.9L^3}{H}\right)^{0.385}$ = 0.100 hours

   Where: T_c = Travel time of water from hydraulically most distant point to point of interest, hours.
   L = Length of longest watercourse, 0.388 miles
   H = Elevation difference, 272 feet

   The time of concentration (T_c) was obtained using Method C as described in Figure 30, "Design of Small Dams", by the United States Department of the Interior, Bureau of Reclamation and was verified using average channel velocity estimates and watercourse lengths.

   Lag Time = 0.060 hours (0.60 Tc)
   Hydrologic Soil Group = 40% B (Winfield, Cedargap and Goss Series) + 60% D (Holstien and Gasconade Series) per County SCS Soil Report.
   Soil type CN = 76 (AMC II, 1 percent probability flood condition)
   = 89 (AMC III, PMF condition)

2. Flow passing the double 18-inch diameter corrugated metal pipe spillway was determined using Bernoulli's equation for flow in pipes. A pipe friction factor (n) of 0.021 was used. Losses, including entrance, pipe and exit loses totaled 3.95 velocity heads for the south pipe and 4.09 velocity heads for the north pipe. Reference "Handbook of Hydraulics", Fifth Edition, King and Brater, pages 8-5 and 8-6.

Discharge quantities, determined by the methods described herein were plotted versus corresponding lake water surface elevations to determine the discharge rating curve for the principal spillway.

3. The emergency spillway section consists of a broad-crested, V-section for which conventional weir formulas do not apply.

Spillway release rates were determined as follows:

a. Spillway crest section properties (area, "a" and top width, "t") were computed for various depths, "d".

b. It was assumed that flow over the spillway crest would occur at critical depth. Flow at critical depth was computed as $Qc = \left(\frac{a^3 g}{t}\right)^{0.5}$ for the various depths, "d". Corresponding velocities (v_c) and velocity heads (H_{vc}) were determined using conventional formulas.* Reference, "Handbook of Hydraulics", Fifth Edition, by King and Brater, page 8-7.

c. Static lake levels corresponding to the various values passing the spillway were computed as critical depths plus critical velocity head ($d_c + H_{vc}$), and the relationship between lake level and spillway discharge was thus obtained. The procedure neglects the minor insignificant friction losses across the length of the spillway.

* $v_c = \frac{Qc}{a}$; $Hvc = \frac{{v_c}^2}{2g}$

4. The discharges for the principal and emergency spillways for equal elevations were summated for entry on the Y4 and Y5 cards.

5. The profile of the dam crest is irregular and flow over the dam cannot be determined by application of conventional weir formulas. Crest length and elevation data for the dam crest proper were entered into the HEC-1 Program on the $L and the $V cards. The program assumes that flow over the dam crest section occurs at critical depth and computes internally the flow over the dam crest and adds this flow to the flow passing the spillways as entered on the Y4 and Y5 cards.

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A1        ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
A2        HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF SKY RANCH LAKE DAM
A3        RATIOS OF PMF ROUTED THROUGH RESERVOIR
B     200         0         5         0         0         0         0         0         0         0
B1      5
J       1         4         1
J1    .10       .15       .50        1.
K       0   INFLOW                                                   1
K1        INFLOW HYDROGRAPH
M       1         2      .207                            1.0                                      1
P       0      25.1       102       120       130
T                                                                  -1      -.05
W2              0.010
X     1.0      -.10       2.0
K       1       DAM                                                  1

K1        RESERVOIR ROUTING BY MODIFIED PULS
Y                                   1         1
Y1      1                                                        50.67        -1
Y4    610       612     613.5     613.8     614.5     614.8       615     615.3       61[illegible]
Y5      0      30.7      34.4      34.9       55.       75.       90.      142.       3[illegible].
$A      0       7.8       11.      14.7
$E    590       610       620       630
$$    610
$D  613.[illegible]
$L      0       117       211       283       307       349       400       450
$V  613.[illegible]  614.1     614.2     614.7     614.9     616.1     618.9     624.1
K      99
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A1       ANALYSIS OF DAM OVERTOPPING USING 100-YR FLOOD
A2       HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF SKY RANCH LAKE DAM
A3       100-YR FLOOD ROUTED THROUGH RESERVOIR
B     288         0       5                                                      4
B1      5
J       1         1       1
J1     1.
K       0   INFLOW                                                  1
K1       INFLOW HYDROGRAPH
M       0         2    .209                      1.0                               1
O     288     7.094
O1   .006      .006    .006    .006    .006    .006    .006    .006    .006    .006
O1   .006      .006    .006    .006    .006    .006    .006    .006    .006    .006
O1   .006      .006    .006    .006    .006    .006    .006    .006    .006    .006
O1   .006      .006    .006    .006    .006    .006    .006    .006    .006    .006
O1   .006      .006    .006    .006    .006    .006    .006    .006    .006    .006
O1   .006      .006    .006    .006    .006    .006    .006    .006    .006    .006
O1   .006      .006    .006    .006    .006    .006    .006    .006    .006    .006
O1   .006      .006    .014    .014    .014    .014    .014    .014    .014    .014
O1   .014      .014    .014    .014    .014    .014    .014    .014    .014    .014
O1   .014      .014    .014    .014    .014    .014    .014    .014    .014    .014
O1   .014      .014    .014    .014    .014    .014    .014    .014    .024    .024
O1   .024      .024    .024    .024    .024    .024    .024    .024    .024    .024
O1   .024      .024    .024    .024    .024    .024    .029    .029    .029    .029
O1   .029      .029    .060    .060    .060    .060    .060    .060    .129    .129
O1   .130      .247    .247    .546    .826    .800    .247    .130    .130    .129
O1   .060      .060    .060    .060    .060    .060    .029    .029    .029    .029
O1   .029      .029    .024    .024    .024    .024    .024    .024    .024    .024
```

100-YR. FLOOD (Cont'd)

O1	.024	.024	.024	.024	.024	.024	.024	.024	.024	.024
O1	.014	.014	.014	.014	.014	.014	.014	.014	.014	.014
O1	.014	.014	.014	.014	.014	.014	.014	.014	.014	.014
O1	.014	.014	.014	.014	.014	.014	.014	.014	.014	.014
O1	.014	.014	.014	.014	.014	.014	.006	.006	.006	.006
O1	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
O1	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
O1	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
O1	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
O1	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
O1	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
O1	.006	.006	.006	.006	.006	.006	.006	.006		
T							-1	-76		
W2		0.060								
X	-1.0	-.10	2.0							
K	1	DAM					1			
K1	RESERVOIR ROUTING BY MODIFIED PULS									
Y				1	1					
Y1	1						50.67	-1		
Y4	610	612	613.5	613.8	614.5	614.8	615	615.3	616	
Y5	0	30.7	34.4	34.9	55.	75.	90.	142.	317.	
$A	0	7.6	11.	14.7						
$E	590	610	620	630						
$$	610									
$D	613.9									
$L	0	117	211	290	307	349	400	450		
$V	613.9	614.1	614.2	614.7	614.9	615.1	616.9	624.1		
K	99									

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ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF [illegible] RANCH LAKE DAM
RATIOS OF PMF ROUTED THROUGH RESERVOIR

                         JOB SPECIFICATION
  NQ    NHR   NMIN   IDAY    IHR   IMIN  METRC   IPLT   IPRT  NSTAN
 288      0      5      0      0      0      0      0      0      0
                     JOPER    NWT  LROPT  TRACE
                         5      0      0      0

                  MULTI-PLAN ANALYSES TO BE PERFORMED
                      NPLAN= 1 NRTIO= 4 LRTIO= 1
RTIOS=    .14    .15    .50   1.00


**********      **********      **********      **********      **********

                      SUB-AREA RUNOFF COMPUTATION

   INFLOW HYDROGRAPH

             ISTAQ  ICOMP  IECON  ITAPE   JPLT   JPRT  INAME ISTAGE  IAUTO
            INFLOW      0      0      0             0      1      0      0

                             HYDROGRAPH DATA
     IHYDG   IUHG  TAREA   SNAP  TRSDA  TRSPC  RATIO  ISNOW  ISAME  LOCAL
         1      2    .21   0.00    .21   1.00  0.000      0      1      0

                              PRECIP DATA
              SPFE    PMS     R6    R12    R24    R48    R72    R96
              0.00  25.10 102.00 120.00 130.00   0.00   0.00   0.00

                              LOSS DATA
LROPT  STRKR  DLTKR  RTIOL  ERAIN  STRKS  RTIOK  STRTL  CNSTL  ALSMX  RTIMP
    0   0.00   0.00   1.00   0.00   0.00   1.00  -1.00 -89.00   0.00   0.00

  CURVE NO =  -89.00  WETNESS =   -1.00  EFFECT CN =   89.00

                          UNIT HYDROGRAPH DATA
                         TC=  0.00    LAG=   .06

                             RECESSION DATA
                  STRTQ=   -1.00   QRCSN=    -.10   RTIOR= 2.00

  TIME INCREMENT TOO LARGE--(NHQ IS GT LAG/2)

  UNIT HYDROGRAPH  6 END OF PERIOD ORDINATES, TC=    0.00 HOURS, LAG=    .06  VOL= 1.00
927.      512.      133.       35.       10.        1.
```

0

END-OF-PERIOD FLOW

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.05	1	.01	0.00	.01	0.	1.01	12.05	145	.21	.21	.01	233.
1.01	.10	2	.01	0.00	.01	0.	1.01	12.10	146	.21	.21	.01	303.
1.01	.15	3	.01	0.00	.01	0.	1.01	12.15	147	.21	.21	.01	328.
1.01	.20	4	.01	0.00	.01	0.	1.01	12.20	148	.21	.21	.01	333.
1.01	.25	5	.01	0.00	.01	0.	1.01	12.25	149	.21	.21	.01	335.
1.01	.30	6	.01	0.00	.01	0.	1.01	12.30	150	.21	.21	.01	336.
1.01	.35	7	.01	0.00	.01	0.	1.01	12.35	151	.21	.21	.01	336.
1.01	.40	8	.01	0.00	.01	0.	1.01	12.40	152	.21	.21	.00	337.
1.01	.45	9	.01	0.00	.01	0.	1.01	12.45	153	.21	.21	.00	337.
1.01	.50	10	.01	0.00	.01	0.	1.01	12.50	154	.21	.21	.00	338.
1.01	.55	11	.01	0.00	.01	0.	1.01	12.55	155	.21	.21	.00	338.
1.01	1.00	12	.01	0.00	.01	0.	1.01	13.00	156	.21	.21	.00	338.
1.01	1.05	13	.01	0.00	.01	0.	1.01	13.05	157	.26	.25	.00	378.
1.01	1.10	14	.01	0.00	.01	0.	1.01	13.10	158	.26	.25	.00	399.
1.01	1.15	15	.01	0.00	.01	0.	1.01	13.15	159	.26	.25	.00	405.
1.01	1.20	16	.01	0.00	.01	0.	1.01	13.20	160	.26	.25	.00	407.
1.01	1.25	17	.01	0.00	.01	0.	1.01	13.25	161	.26	.25	.00	408.
1.01	1.30	18	.01	.00	.01	0.	1.01	13.30	162	.26	.25	.00	408.
1.01	1.35	19	.01	.00	.01	0.	1.01	13.35	163	.26	.25	.00	409.
1.01	1.40	20	.01	.00	.01	1.	1.01	13.40	164	.26	.25	.00	409.
1.01	1.45	21	.01	.00	.01	1.	1.01	13.45	165	.26	.25	.00	409.
1.01	1.50	22	.01	.00	.01	2.	1.01	13.50	166	.26	.25	.00	409.
1.01	1.55	23	.01	.00	.01	2.	1.01	13.55	167	.26	.25	.00	409.
1.01	2.00	24	.01	.00	.01	2.	1.01	14.00	168	.26	.25	.00	410.
1.01	2.05	25	.01	.00	.01	3.	1.01	14.05	169	.32	.32	.00	459.
1.01	2.10	26	.01	.00	.01	3.	1.01	14.10	170	.32	.32	.00	501.
1.01	2.15	27	.01	.00	.01	4.	1.01	14.15	171	.32	.32	.00	510.
1.01	2.20	28	.01	.00	.01	4.	1.01	14.20	172	.32	.32	.00	512.
1.01	2.25	29	.01	.00	.01	4.	1.01	14.25	173	.32	.32	.00	513.
1.01	2.30	30	.01	.00	.01	5.	1.01	14.30	174	.32	.32	.00	513.
1.01	2.35	31	.01	.00	.01	5.	1.01	14.35	175	.32	.32	.00	514.
1.01	2.40	32	.01	.00	.01	5.	1.01	14.40	176	.32	.32	.00	514.
1.01	2.45	33	.01	.00	.01	6.	1.01	14.45	177	.32	.32	.00	514.
1.01	2.50	34	.01	.00	.01	6.	1.01	14.50	178	.32	.32	.00	514.
1.01	2.55	35	.01	.00	.01	6.	1.01	14.55	179	.32	.32	.00	514.
1.01	3.00	36	.01	.00	.01	7.	1.01	15.00	180	.32	.32	.00	514.
1.01	3.05	37	.01	.00	.01	7.	1.01	15.05	181	.19	.19	.00	399.
1.01	3.10	38	.01	.00	.01	7.	1.01	15.10	182	.39	.39	.00	514.
1.01	3.15	39	.01	.00	.01	8.	1.01	15.15	183	.39	.39	.00	597.
1.01	3.20	40	.01	.00	.01	8.	1.01	15.20	184	.58	.58	.00	798.
1.01	3.25	41	.01	.01	.01	8.	1.01	15.25	185	.68	.68	.00	993.
1.01	3.30	42	.01	.01	.01	8.	1.01	15.30	186	1.65	1.65	.01	1968.
1.01	3.35	43	.01	.01	.01	9.	1.01	15.35	187	2.72	2.71	.01	3474.
1.01	3.40	44	.01	.01	.01	9.	1.01	15.40	188	1.07	1.07	.00	2629.
1.01	3.45	45	.01	.01	.01	9.	1.01	15.45	189	.68	.68	.00	1602.
1.01	3.50	46	.01	.01	.01	9.	1.01	15.50	190	.58	.58	.00	1141.
1.01	3.55	47	.01	.01	.01	10.	1.01	15.55	191	.39	.39	.00	813.
1.01	4.00	48	.01	.01	.01	10.	1.01	16.00	192	.39	.39	.00	672.
1.01	4.05	49	.01	.01	.01	10.	1.01	16.05	193	.30	.30	.00	555.
1.01	4.10	50	.01	.01	.01	10.	1.01	16.10	194	.30	.30	.00	500.
1.01	4.15	51	.01	.01	.01	10.	1.01	16.15	195	.30	.30	.00	486.

PMF END-OF-PERIOD FLOW

1.01	4.20	52	.01	.01	.01	11.	1.01	16.20	196	.30	.30	.00	483.
1.01	4.25	53	.01	.01	.01	11.	1.01	16.25	197	.30	.30	.00	482.
1.01	4.30	54	.01	.01	.01	11.	1.01	16.30	198	.30	.30	.00	482.
1.01	4.35	55	.01	.01	.01	11.	1.01	16.35	199	.30	.30	.00	482.
1.01	4.40	56	.01	.01	.01	11.	1.01	16.40	200	.30	.30	.00	482.
1.01	4.45	57	.01	.01	.01	12.	1.01	16.45	201	.30	.30	.00	482.
1.01	4.50	58	.01	.01	.01	12.	1.01	16.50	202	.30	.30	.00	482.
1.01	4.55	59	.01	.01	.01	12.	1.01	16.55	203	.30	.30	.00	482.
1.01	5.00	60	.01	.01	.01	12.	1.01	17.00	204	.30	.30	.00	482.
1.01	5.05	61	.01	.01	.01	12.	1.01	17.05	205	.23	.23	.00	423.
1.01	5.10	62	.01	.01	.01	12.	1.01	17.10	206	.23	.23	.00	390.
1.01	5.15	63	.01	.01	.01	13.	1.01	17.15	207	.23	.23	.00	382.
1.01	5.20	64	.01	.01	.01	13.	1.01	17.20	208	.23	.23	.00	380.
1.01	5.25	65	.01	.01	.01	13.	1.01	17.25	209	.23	.23	.00	379.
1.01	5.30	66	.01	.01	.01	13.	1.01	17.30	210	.23	.23	.00	379.
1.01	5.35	67	.01	.01	.01	13.	1.01	17.35	211	.23	.23	.00	379.
1.01	5.40	68	.01	.01	.01	13.	1.01	17.40	212	.23	.23	.00	379.
1.01	5.45	69	.01	.01	.01	13.	1.01	17.45	213	.23	.23	.00	379.
1.01	5.50	70	.01	.01	.01	13.	1.01	17.50	214	.23	.23	.00	379.
1.01	5.55	71	.01	.01	.01	14.	1.01	17.55	215	.23	.23	.00	379.
1.01	6.00	72	.01	.01	.01	14.	1.01	18.00	216	.23	.23	.00	379.
1.01	6.05	73	.06	.04	.02	42.	1.01	18.05	217	.02	.02	.00	328.
1.01	6.10	74	.06	.04	.02	59.	1.01	18.10	218	.02	.02	.00	[illegible]
1.01	6.15	75	.06	.04	.02	65.	1.01	18.15	219	.02	.02	.00	285.
1.01	6.20	76	.06	.04	.02	68.	1.01	18.20	220	.02	.02	.00	266.
1.01	6.25	77	.06	.04	.02	71.	1.01	18.25	221	.02	.02	.00	248.
1.01	6.30	78	.06	.05	.02	72.	1.01	18.30	222	.02	.02	.00	232.
1.01	6.35	79	.06	.05	.02	74.	1.01	18.35	223	.02	.02	.00	216.
1.01	6.40	80	.06	.05	.02	75.	1.01	18.40	224	.02	.02	.00	202.
1.01	6.45	81	.06	.05	.02	76.	1.01	18.45	225	.02	.02	.00	189.
1.01	6.50	82	.06	.05	.01	78.	1.01	18.50	226	.02	.02	.00	176.
1.01	6.55	83	.06	.05	.01	79.	1.01	18.55	227	.02	.02	.00	164.
1.01	7.00	84	.06	.05	.01	80.	1.01	19.00	228	.02	.02	.00	153.
1.01	7.05	85	.06	.05	.01	81.	1.01	19.05	229	.02	.02	.00	143.
1.01	7.10	86	.06	.05	.01	82.	1.01	19.10	230	.02	.02	.00	133.
1.01	7.15	87	.06	.05	.01	83.	1.01	19.15	231	.02	.02	.00	124.
1.01	7.20	88	.06	.05	.01	83.	1.01	19.20	232	.02	.02	.00	116.
1.01	7.25	89	.06	.05	.01	84.	1.01	19.25	233	.02	.02	.00	108.
1.01	7.30	90	.06	.05	.01	85.	1.01	19.30	234	.02	.02	.00	101.
1.01	7.35	91	.06	.05	.01	86.	1.01	19.35	235	.02	.02	.00	94.
1.01	7.40	92	.06	.05	.01	86.	1.01	19.40	236	.02	.02	.00	88.
1.01	7.45	93	.06	.05	.01	87.	1.01	19.45	237	.02	.02	.00	82.
1.01	7.50	94	.06	.05	.01	87.	1.01	19.50	238	.02	.02	.00	76.
1.01	7.55	95	.06	.05	.01	88.	1.01	19.55	239	.02	.02	.00	71.
1.01	8.00	96	.06	.05	.01	88.	1.01	20.00	240	.02	.02	.00	67.
1.01	8.05	97	.06	.06	.01	89.	1.01	20.05	241	.02	.02	.00	62.
1.01	8.10	98	.06	.06	.01	89.	1.01	20.10	242	.02	.02	.00	58.
1.01	8.15	99	.06	.06	.01	90.	1.01	20.15	243	.02	.02	.00	54.
1.01	8.20	100	.06	.06	.01	90.	1.01	20.20	244	.02	.02	.00	50.
1.01	8.25	101	.06	.06	.01	90.	1.01	20.25	245	.02	.02	.00	47.
1.01	8.30	102	.06	.06	.01	91.	1.01	20.30	246	.02	.02	.00	44.
1.01	8.35	103	.06	.06	.01	91.	1.01	20.35	247	.02	.02	.00	41.

PMF END-OF-PERIOD FLOW

1.01	8.40	104	.06	.06	.01	91.	1.01	20.40	248	.02	.02	.00	38.
1.01	8.45	105	.06	.06	.01	91.	1.01	20.45	249	.02	.02	.00	36.
1.01	8.50	106	.06	.06	.01	92.	1.01	20.50	250	.02	.02	.00	34.
1.01	8.55	107	.06	.06	.01	92.	1.01	20.55	251	.02	.02	.00	34.
1.01	9.00	108	.06	.06	.01	93.	1.01	21.00	252	.02	.02	.00	34.
1.01	9.05	109	.06	.06	.01	93.	1.01	21.05	253	.02	.02	.00	34.
1.01	9.10	110	.06	.06	.01	93.	1.01	21.10	254	.02	.02	.00	34.
1.01	9.15	111	.06	.06	.00	93.	1.01	21.15	255	.02	.02	.00	34.
1.01	9.20	112	.06	.06	.00	94.	1.01	21.20	256	.02	.02	.00	34.
1.01	9.25	113	.06	.06	.00	94.	1.01	21.25	257	.02	.02	.00	34.
1.01	9.30	114	.06	.06	.00	94.	1.01	21.30	258	.02	.02	.00	34.
1.01	9.35	115	.06	.06	.00	94.	1.01	21.35	259	.02	.02	.00	34.
1.01	9.40	116	.06	.06	.00	94.	1.01	21.40	260	.02	.02	.00	34.
1.01	9.45	117	.06	.06	.00	95.	1.01	21.45	261	.02	.02	.00	34.
1.01	9.50	118	.06	.06	.00	95.	1.01	21.50	262	.02	.02	.00	34.
1.01	9.55	119	.06	.06	.00	95.	1.01	21.55	263	.02	.02	.00	34.
1.01	10.00	120	.06	.06	.00	95.	1.01	22.00	264	.02	.02	.00	34.
1.01	10.05	121	.06	.06	.00	95.	1.01	22.05	265	.02	.02	.00	34.
1.01	10.10	122	.06	.06	.00	95.	1.01	22.10	266	.02	.02	.00	34.
1.01	10.15	123	.06	.06	.00	96.	1.01	22.15	267	.02	.02	.00	34.
1.01	10.20	124	.06	.06	.00	96.	1.01	22.20	268	.02	.02	.00	34.
1.01	10.25	125	.06	.06	.00	96.	1.01	22.25	269	.02	.02	.00	34.
1.01	10.30	126	.06	.06	.00	96.	1.01	22.30	270	.02	.02	.00	34.
1.01	10.35	127	.06	.06	.00	96.	1.01	22.35	271	.02	.02	.00	34.
1.01	10.40	128	.06	.06	.00	96.	1.01	22.40	272	.02	.02	.00	34.
1.01	10.45	129	.06	.06	.00	96.	1.01	22.45	273	.02	.02	.00	34.
1.01	10.50	130	.06	.06	.00	96.	1.01	22.50	274	.02	.02	.00	34.
1.01	10.55	131	.06	.06	.00	97.	1.01	22.55	275	.02	.02	.00	34.
1.01	11.00	132	.06	.06	.00	97.	1.01	23.00	276	.02	.02	.00	34.
1.01	11.05	133	.06	.06	.00	97.	1.01	23.05	277	.02	.02	.00	34.
1.01	11.10	134	.06	.06	.00	97.	1.01	23.10	278	.02	.02	.00	34.
1.01	11.15	135	.06	.06	.00	97.	1.01	23.15	279	.02	.02	.00	34.
1.01	11.20	136	.06	.06	.00	97.	1.01	23.20	280	.02	.02	.00	34.
1.01	11.25	137	.06	.06	.00	97.	1.01	23.25	281	.02	.02	.00	34.
1.01	11.30	138	.06	.06	.00	97.	1.01	23.30	282	.02	.02	.00	34.
1.01	11.35	139	.06	.06	.00	97.	1.01	23.35	283	.02	.02	.00	34.
1.01	11.40	140	.06	.06	.00	97.	1.01	23.40	284	.02	.02	.00	34.
1.01	11.45	141	.06	.06	.00	98.	1.01	23.45	285	.02	.02	.00	34.
1.01	11.50	142	.06	.06	.00	98.	1.01	23.50	286	.02	.02	.00	34.
1.01	11.55	143	.06	.06	.00	98.	1.01	23.55	287	.02	.02	.00	34.
1.01	12.00	144	.06	.06	.00	98.	1.02	0.00	288	.02	.02	.00	34.

SUM 32.63 31.19 1.44 53524.
(829.)(792.)(37.)(1515.63)

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	3471.	579.	186.	186.	53511.
CMS	98.	16.	5.	5.	1515.
INCHES		25.37	33.08	33.08	33.08
MM		644.49	840.22	840.22	840.22
AC-FT		283.	369.	369.	369.
THOUS CU M		349.	455.	455.	455.

SURFACE AREA=	0.	8.	11.	15.
CAPACITY=	0.	51.	143.	271.
ELEVATION=	590.	610.	620.	630.

SUMMARY OF DAM SAFETY ANALYSIS

RATIOS OF PMF

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	610.00	610.00	613.90
STORAGE	51.	51.	83.
OUTFLOW	0.	0.	38.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.14	613.80	0.00	82.	35.	0.00	[illegible]	[illegible]
.15	614.03	.13	84.	45.	[illegible]	[illegible]	[illegible]
.50	615.41	1.51	96.	1435.	7.42	[illegible]	[illegible]
1.00	616.15	2.25	104.	2998.	11.07	[illegible]	[illegible]

SUMMARY OF DAM SAFETY ANALYSIS

100-YEAR FLOOD

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	610.00	610.00	613.90
STORAGE	51.	51.	83.
OUTFLOW	0.	0.	38.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	613.74	0.00	81.	35.	0.00	14.00	0.00